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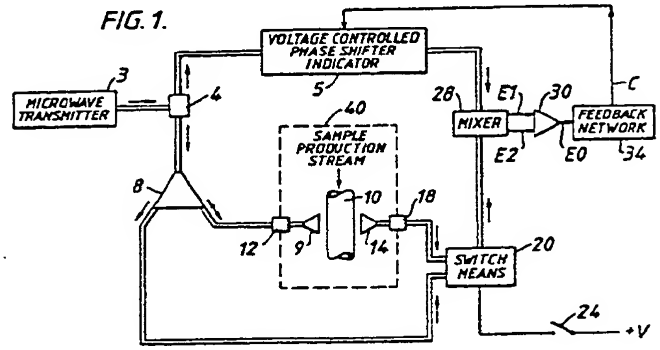
(54) Petroleum stream microwave watercut monitor.

(57) A microwave watercut monitor includes a test cell having a petroleum stream flowing through it while permitting the microwave energy to enter the test cell. A microwave source provides microwave energy to a circulator which in turn provides the microwave energy to an antenna. The antenna provides the petroleum stream in the test cell with the microwave energy and receives reflected microwave energy back from the stream. The reflected microwave energy is provided by the antenna to the circulator which in turn provides the reflected microwave energy as test microwave energy. Indicator apparatus provides an indication of the watercut of the petroleum stream in accordance with the phase difference between the source provided microwave energy and the test microwave energy. In one embodiment a detector assembly is connected to the circulator and detects the intensity of the test microwave energy to provide a corresponding intensity signal.

The indicator apparatus is connected to the circulator to the microwave source and to the detector assembly to provide an indication of the watercut in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

FIG. 1.



EP 0 372 843 A1

PETROLEUM STREAM MICROWAVE WATERCUT MONITOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to petroleum stream monitors in general and, more particularly, to petroleum stream watercut monitors.

SUMMARY OF THE INVENTION

The petroleum stream watercut monitor includes a test cell having a petroleum stream flowing through it. A microwave transmitter provides microwave energy through an antenna with, in some embodiments, an isolator therebetween. The antenna irradiates the test cell with the microwave energy so that the microwave energy enters the test cell and is reflected from the petroleum stream back to the antenna. A circulator connects the transmitter to the antenna through isolator means, when provided, and receives from the antenna again through the isolator, when provided, the reflected microwave energy to provide test microwave energy. Alternatively the test microwave energy may be microwave energy passed through the test cell and received by a second antenna. An indicator provides an indication of the watercut of the petroleum stream in accordance with the phase difference between the transmitted microwave energy and the test microwave energy.

In further embodiments a co-variance microwave water cut monitor includes a test cell having a petroleum stream flowing through it while permitting the microwave energy to enter the test cell. A microwave source provides microwave energy to a circulator which in turn provides the microwave energy to an antenna. The antenna provides the petroleum stream in the test cell with the microwave energy and receives reflected microwave energy back from the stream. The reflected microwave energy is provided by the antenna to the circulator which in turn provides the reflected microwave energy as test microwave energy. A detector assembly connected to the circulator detects the intensity of the test microwave energy and provides a corresponding intensity signal. Indicator apparatus connected to the circulator to the microwave source and to the detector assembly provides an indication of the water cut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

In another embodiment there is a second antenna which receives microwave energy that has passed through the petroleum stream and provides the received microwave energy as the test microwave energy. The detector assembly is connected to the second antenna and again provides an intensity signal corresponding to the intensity of the test microwave energy. Similarly the indicator apparatus is also connected to the second antenna instead of the circulator and provides the indication of the water cut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

The objects and advantages of the invention will appear more fully hereinafter, from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein two embodiments are illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustrative purposes only and are not to be construed as defining the limits of the invention.

DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings, in which :-

Figure 1 is a combination simplified block diagram and a schematic of a watercut monitor constructed in accordance with the present invention;

Figure 2 is a side elevation of an isolator of the apparatus of Figure 1;

Figure 3A is a side elevation of one of the wave guides forming the isolator of Figure 2;

Figure 3B is a front elevation of the wave guide of Figure 3A; and

Figure 4 is a partial simplified block diagram of a microwave water cut monitor according to a second embodiment.

DESCRIPTION OF THE INVENTION

The water cut monitor shown in Figure 1 includes a microwave source 3 providing electromagnetic energy, hereinafter referred to as microwave energy, at a microwave frequency. Source 3 is low

powered and may use a microwave gun source. Source 3 provides microwave energy to directional coupler 4. Directional coupler 4 provides microwave energy to a conventional type voltage controlled phase shifter 5 and to a circulator 8. All conductance or carrying of microwave energy is accomplished by using conventional type waveguides and coaxial cable.

Circulator 8 provides microwave energy to an antenna 9 which has, in this embodiment, an isolator 12 interconnecting antenna 9 which has, in this embodiment, an isolator 12 interconnecting antenna 9 to circulator 8. Antenna 9 transmits or radiates the microwave energy through a sample stream of a fluid mixture passing through a test cell 10. Test cell 10 may be a portion of a pipeline with "windows" made of material which permits passage of the microwave energy or it may be a portion of the pipeline made of the "window" material. The transmitted microwave energy passes through the fluid mixture and is received by an antenna 14 which provides the received microwave energy to a switch means 20.

The fluid mixture also reflects some of the microwave energy back to antenna 9 which passes back through antenna 9 to circulator 8. Circulator 8 blocks the reflected microwave energy from feeding back to source 3 and provides the reflected microwave energy to switch means 20. Reflected microwave energy becomes more important as the distance between antennas 9 and 14 increases. This is especially true where a large pipeline carrying the fluid mixture is being monitored.

A positive direct current voltage +V is provided to a switch means 24 which is connected to switch means 20. With switch means 24 open, switch means 20 provides microwave energy from antenna 14 as test microwave energy. When switch 24 is closed, the reflected microwave energy from circulator 8 is provided by switch means 20 as the test microwave energy.

The microwave energy from voltage control phase shifter 5, hereinafter called the reference microwave energy, and the test microwave energy from switch 20, are provided to a mixer 28 which mixes them to provide two electrical signals E1, E2, representative of the phases of the reference microwave energy and the test microwave energy.

A differential amplifier 30 provides an output signal E0 in accordance with the difference between signals E1 and E2. Signal E0 is a function of the phase difference between the reference microwave energy and the test microwave energy. Signal E0 may be applied to an indicator in which the amplitude of E0 will be representative of the phase difference or as shown in the present example may be provided to a feedback network 34. Feedback network 34 provides a control voltage C to voltage control phase shifter 5 controlling the phase of the reference microwave energy. Signal E0, and hence the control voltage C, decreases in amplitude until there is substantially 90° phase difference between the reference microwave energy and the test microwave energy. Voltage control phase shifter 5 indicates the amount of phase shift required to eliminate the phase difference.

With reference to Figure 2, there is shown isolator 12. Isolator 12 is used to protect an area adjacent test cell 10 from potential explosions. This unsafe area, which may be of any size, is shown in Figure 1 by dashed line 40.

The possibility of an explosion arises since many of the energy controlling components of the watercut monitor are made of metal for optimal microwave transmission. As such, all energy generated in the watercut circuits could be conducted to antennas 9 and 14. Under normal operating conditions, energy is limited to safe levels not capable of causing an explosion. In the event of accident or misuse of the watercut monitor much higher energy and energy of non-microwave frequencies could be applied to antennas 9 and 14.

Isolators 12 and 18 isolate antennas 9 and 14 from the buildup voltages that may occur on any of the other elements and thus protect them from arcing and causing an explosion.

Isolator 12 is made up of two identical wave guides 44 which is shown in Figures 3A and 3B. Wave guides 44 include mounting flanges 48, a guide element 52, insulators 57 and a metal jack 60. Metal jack 60 is isolated from the wave guide 52 so that any voltage buildup on jack 60 does not appear on guide element 52. As can be seen in Figure 3B, the RF energy aperture is identified by the numeral 65. It should be noted that although isolator 12 is shown with both jacks 60 facing downward it is obvious to one skilled in the art that one of the wave guides 44 may be reorientated 180° without loss of cross-sectional area of aperture 65, if it is so desired to do so.

The present invention has been described as being used with a water cut monitor of the type described and disclosed in U.S.P. 4,499,418, but it may also be used in either situation where a water cut monitor uses microwave energy singularly either as a direct passthrough type of measurement or in another configuration as a reflected microwave energy configuration.

The embodiment shown in Figure 4 is a modification of the apparatus shown in Figure 1. The same parts have been given the same reference numerals in Figures 1 and 4. The description of this embodiment will be restricted to the modified portions of the apparatus of the Figure 4 embodiment.

In the Figure 4 embodiment the switch means

20 provides test microwave energy to a directional coupler 18. Directional coupler 18 provides the test microwave energy to a detector 22 as well as to mixer 28. Detector 22 provides a signal E3 corresponding to the intensity of the microwave energy received by antenna 14. Feedback network 34 provides signal C to voltage control phase shifter 5, controlling the phase of the reference microwave energy, and also to a mini-computer means 40. Signals E3 and C are provided to mini-computer means 40 which contains within it memory means having data related to phase and amplitude for various percentages of water cuts that could be encountered in the production stream. Phase Shifter 5 also provides an enabling signal to computer means 40 allowing computer means 40 to utilize signals C and E3 to select the proper water cut value computer means 40 provides signals, corresponding to the selected water cut value, to readout means 41 which may be either digital display means or record means or a combination of the two.

Claims

1 . A petroleum stream microwave watercut monitor comprising:
test cell means for having a petroleum stream flowing through it while permitting microwave energy to enter the test cell means,
source means for transmitting microwave energy,
antenna means for irradiating the stream flowing in the test cell means with microwave energy and for receiving reflected microwave energy back from the stream in the test cell means,
circulating means connected to the source means and to the antenna means for providing the microwave energy from the source means to the antenna means and for providing reflected microwave energy from the antenna means as test microwave energy, and
indicator means for providing an indication of the watercut of the petroleum stream in accordance with the phase difference between the transmitted microwave energy and the test microwave energy.

2. A monitor as claimed in claim 1 including isolator means connected to the antenna means for passing microwave energy to and from the antenna means while isolating the antenna means from extraneous energies that may arise in the water cut monitor so as to prevent an accidental explosion due to those extraneous energies.

3. A petroleum stream microwave watercut monitor comprising:
test cell means for having a petroleum stream flowing through it while permitting microwave energy to pass through the test cell means,
source means for transmitting microwave energy,
first antenna means for irradiating the stream flowing in the test cell means with microwave energy from said source means,
second antenna means for receiving microwave energy that has passed through the stream flowing in the test cell means to provide received microwave energy, and
indicating means for providing an indication of the watercut of the petroleum stream in accordance with the phase difference between the transmitted microwave energy and the received microwave energy.

4. A monitor as claimed in claim 3 including:
first isolating means connecting the source means to the first antenna means for passing microwave energy to the first antenna means while isolating the first antenna means from extraneous energies that may arise in the water cut monitor so as to prevent an accidental explosion due to those extraneous energies,
second isolating means connected to the second antenna means for passing received microwave energy from the second antenna means while isolating the second antenna means from extraneous energies that may arise in the water cut monitor so as to prevent an accidental explosion due to those extraneous energies.

5. A petroleum stream microwave watercut monitor comprising:
test cell means for having a petroleum stream flowing through it while permitting microwave energy to enter the test cell means,
source means for providing microwave energy,
antenna means for providing the petroleum stream flowing in the test cell means with microwave energy and for receiving reflected microwave energy back from the stream in the test cell means,
circulating means connected to the source means and to the antenna means for providing the microwave energy from the source means to the antenna means and for providing reflected microwave energy from the antenna means as test microwave energy,
detector means connected to the circulating means for detecting the intensity of the test microwave energy and providing an intensity signal corresponding thereto, and
indicator means connected to the circulating means, to the source means and to the detector means for providing an indication of the watercut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

6. A petroleum stream microwave watercut monitor comprising:
test cell means for having a petroleum stream

flowing through it while permitting microwave energy to enter the test cell means,
source means for providing microwave energy,
first antenna means connected to the source means for irradiating the petroleum stream flowing in the test cell means with microwave energy,
second antenna means for receiving microwave energy that has passed through the petroleum stream and providing it as test microwave energy,
detector means connected to the second antenna means for detecting the intensity of the test microwave energy and providing an intensity signal corresponding thereto, and
indicator means connected to the second antenna means, to the source means and to the detector means for providing an indication of the watercut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

7. A monitor as claimed in any one of claims 1-4 in which the indicator means further comprises:
a voltage controlled phase shifter receiving the transmitted microwave energy from said source means for phase shifting the transmitted microwave energy in accordance with phase shift signal to provide a reference microwave energy and for providing an indication of the above phase shift, and
phase shift signal means receiving the reference microwave energy and the received microwave energy for providing the phase shift signal to the phase shifter until there is substantially a 90° phase difference between the reference microwave energy and the received microwave energy at which time the phase shifter's indicated phase shift corresponds to the water cut of the petroleum stream.

8. A monitor as claimed in claim 5 or claim 6 in which the indicator means further comprises:
a voltage controlled phase shifter receiving the microwave energy from said source means for phase shifting the source provided microwave energy in accordance with a phase shift signal to provide a reference microwave energy and to provide an enabling signal when the phase shifting is completed, and
phase shift signal means receiving the reference microwave energy and the test microwave energy for providing the phase shift signal to the phase shifter until there is substantially a 90° phase difference between the reference microwave energy and the test microwave energy at which time the phase shifter's indicated phase shift corresponds to the water cut of the petroleum stream.

9. A monitor as claimed in claim 7 or claim 8 in which the phase shift signal means includes:
mixer means connected to the circulating means for mixing the reference microwave energy from the phase shifter with the reflected, or received, microwave energy to provide two signals representative of the phases of the reference microwave energy and the reflected, or received, microwave energy, and
a differential amplifier connected to the mixer means for providing an output signal in accordance with the difference between the two signals from the mixer means, and
a feedback network connected to the phase shifter and to the differential amplifier which provides the phase shift signal in accordance with the output signal.

10. A monitor as claimed in claims 8 and 9 in which the indicator means further includes:
water cut means connected to the phase shifter, to the detector means and to the phase shift signal means and responsive to the enabling signal from the phase shifter for determining the water cut of the petroleum stream in accordance with the intensity signal and the phase shift, and providing water cut signals corresponding thereto.

11 . A monitor as claimed in claim 10 in which the indicator means further includes:
read-out means connected to the computer means for providing a read-out of the selected water-cut value in accordance with the water cut signals from the computer means.

12. A monitor as claimed in claim 2 or claim 4 in which the, or each, isolator means includes
first port means for receiving microwave energy to and from the circulating means,
second port means for providing microwave energy,
first insulator means for providing electrical insulation,
second insulator means for providing electrical insulation, and
body means having an internal passageway and connected to the first and second port means and to the first and second insulator means in a predetermined manner for conveying microwave energy from the first port means to the second port means while providing isolation such that any extraneous energy appearing on one port means is not conducted to the other port means.

13. A petroleum stream microwave watercut monitoring method comprising the steps of:
providing microwave energy from a source,
using antenna means to provide a petroleum stream with the microwave energy from the source,
receiving reflected microwave energy back from the petroleum stream with the antenna means,
using circulator means connected to the source and to the antenna to provide the microwave energy from the source means to the antenna means and to provide the reflected microwave energy from the antenna means as test microwave energy,

detecting the intensity of the test microwave energy,
providing an intensity signal corresponding to the detected intensity of the test microwave energy, and
providing an indication of the watercut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

14. A petroleum stream microwave watercut monitoring method comprising the steps of:
providing microwave energy with a source,
first antenna means connected to the source means for providing the petroleum stream flowing in the test cell means with microwave energy from the source with first antenna means,
receiving microwave energy that has passed through the petroleum stream with second antenna means,
providing the received microwave energy as test microwave energy,
detecting the intensity of the test microwave energy,
providing an intensity signal corresponding to the detected intensity of the test microwave energy, and
providing an indication of the watercut of the petroleum stream in accordance with the intensity signal and the phase difference between the source provided microwave energy and the test microwave energy.

15. A method as described in claim 13 or claim 14, in which the indicator step further comprises:
phase shifting the source provided microwave energy in accordance with a phase shift signal to provide a reference microwave energy,
providing an enabling signal when the phase shifting is completed, and
providing the phase shift signal until there is substantially a 90° phase difference between the reference microwave energy and the test microwave energy.

16. A method as described in claim 15 in which the phase shift signal step includes:
mixing the reference microwave energy with the test microwave energy to provide two signals representative of the phases of the reference microwave energy and the test microwave energy from the circulating means,
providing an output signal in accordance with the difference between the two signals from the mixer step, and
providing the phase shift signal in accordance with the output signal.

17. A method as described in claim 16 in which the indicator means further includes:
determining the water cut of the petroleum stream in accordance with the intensity signal and the phase shift signal, and
providing water cut signals corresponding to the determined water cut.

18. A monitor as described in claim 17 in which the indicator step further includes:
providing a read-out of the selected water-cut value in accordance with the water cut signals.

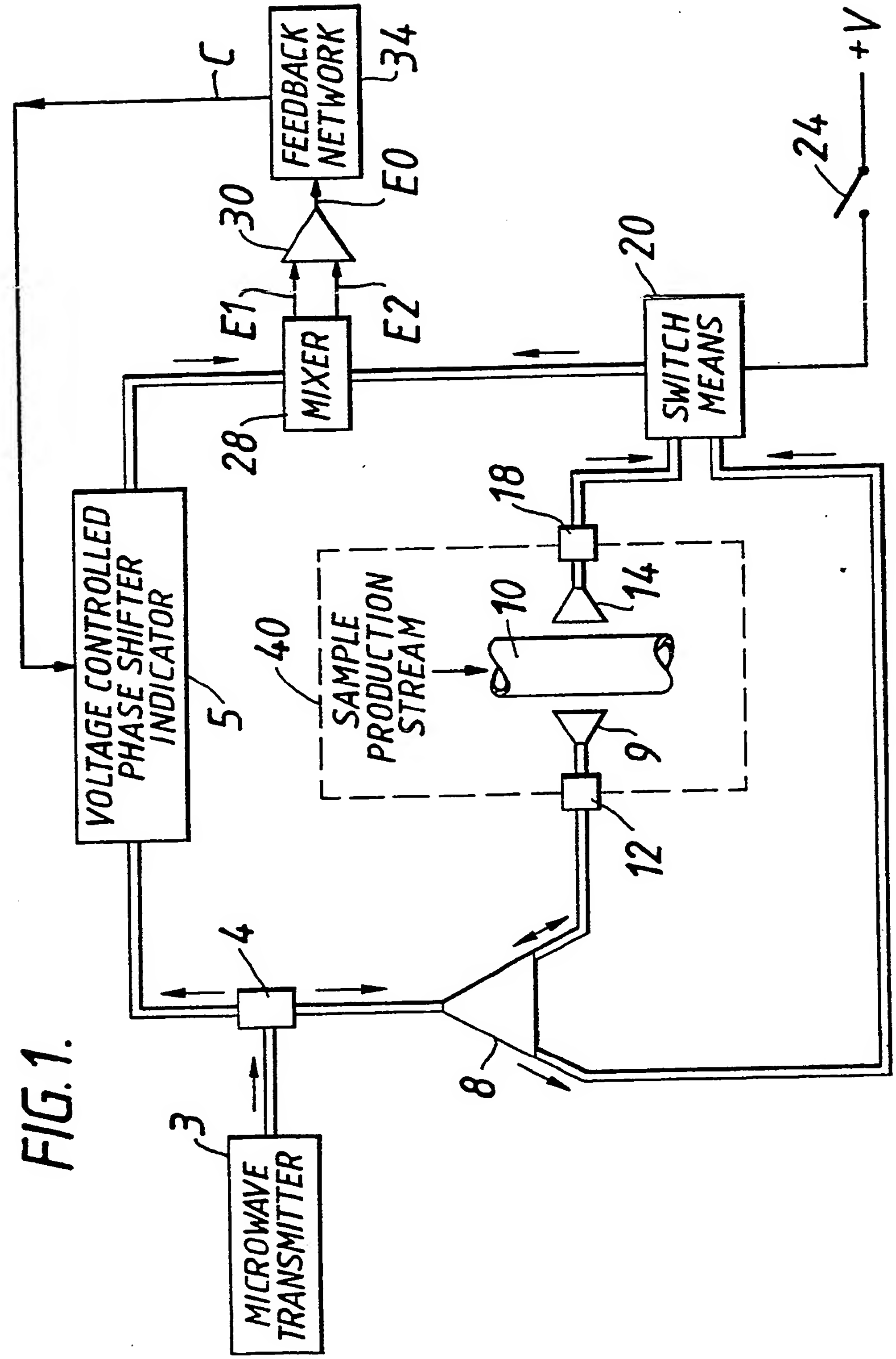

FEEDBACK NETWORK
34
C
E0
30
E1
E2
MIXER
28
SWITCH MEANS
20
24
+V
18
VOLTAGE CONTROLLED PHASE SHIFTER INDICATOR
5
SAMPLE PRODUCTION STREAM
40
10
14
9
12
4
8
MICROWAVE TRANSMITTER
3

FIG. 1.

FIG. 2.

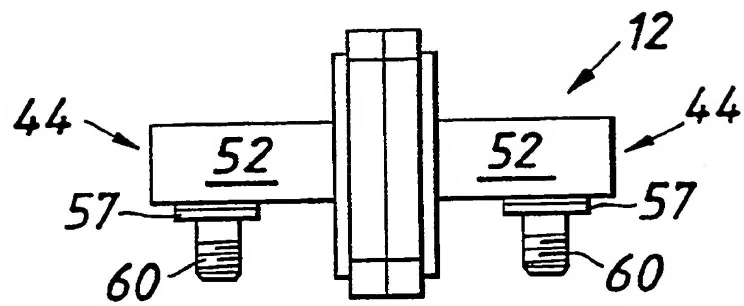


FIG. 3A.

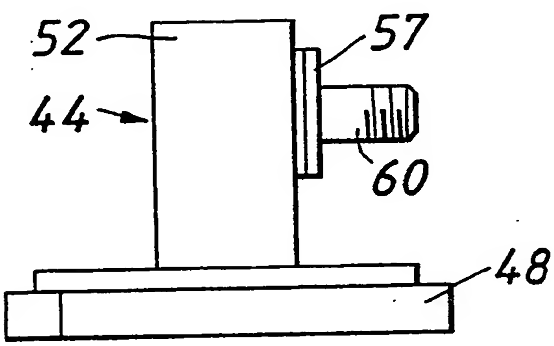
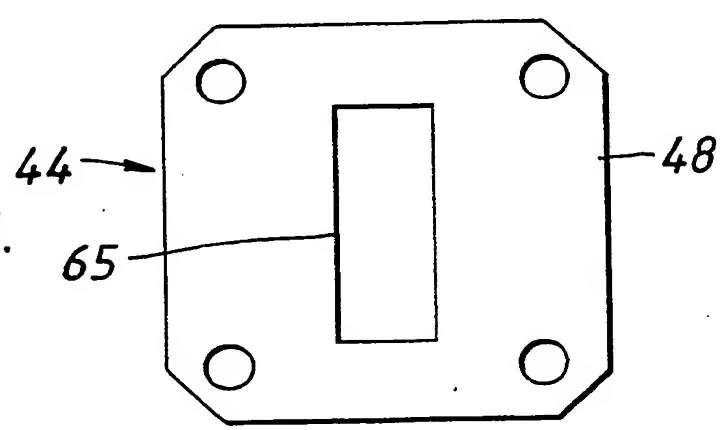


FIG. 3B.



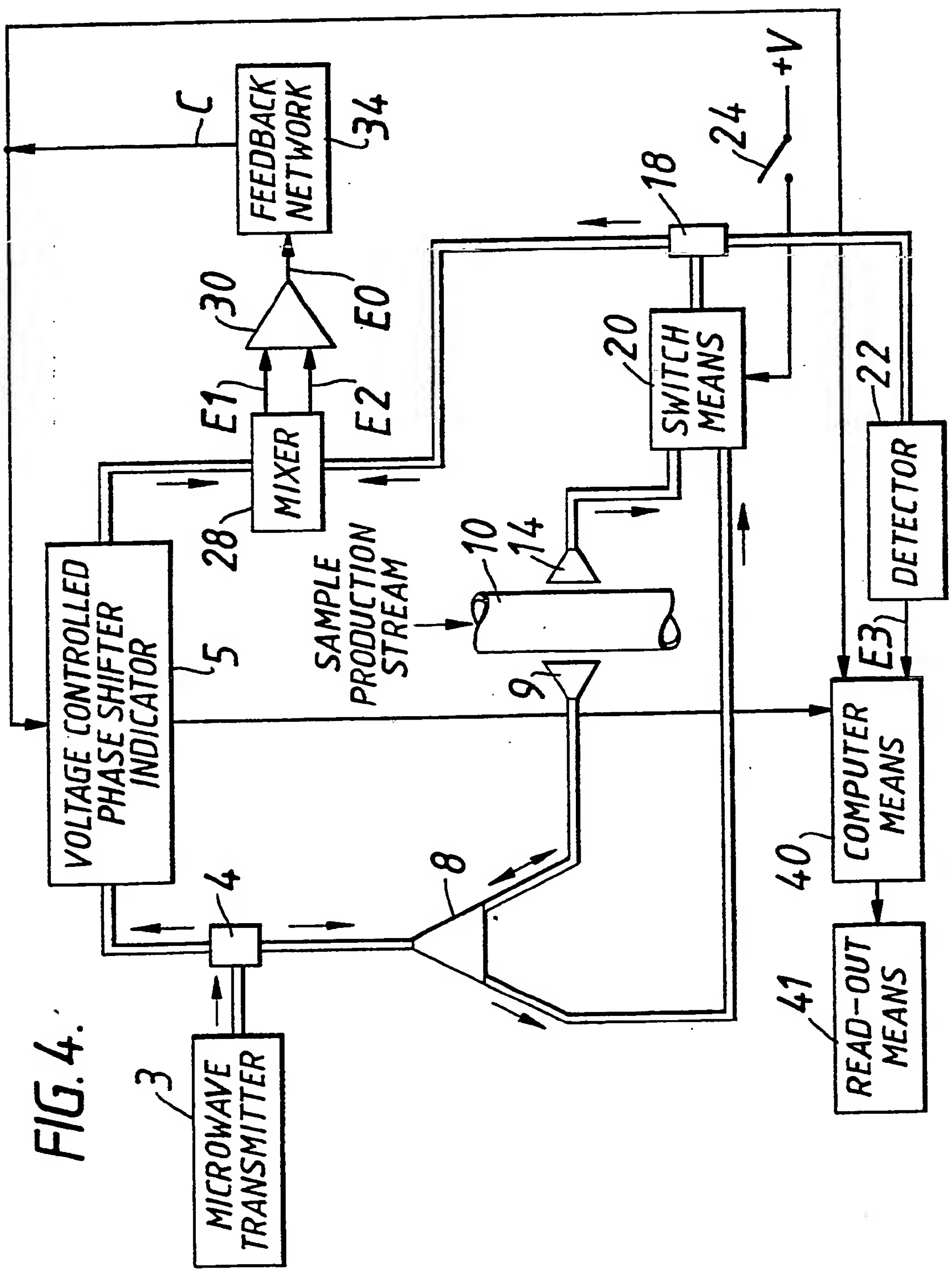

MICROWAVE TRANSMITTER
3
4
VOLTAGE CONTROLLED PHASE SHIFTER INDICATOR
5
8
9
10
14
SAMPLE PRODUCTION STREAM
MIXER
28
E1
E2
30
E0
FEEDBACK NETWORK
34
C
18
20
SWITCH MEANS
24
+V
22
DETECTOR
E3
COMPUTER MEANS
40
READ-OUT MEANS
41

FIG. 4.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 31 2536

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,X D,Y	US-A-4 499 418 (HELMS et al.) * Whole document * ---	1,3,7,9 2,4,5,6,8-11,13-18	G 01 N 22/04 G 01 N 33/28
Y	EP-A-0 268 399 (ATLANTIC RICHFIELD) * Figure 2; column 9, lines 2-25 * ---	2,4	
Y	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS AND CONTROL INSTRUMENTATION, vol. IECI-23, no. 4, November 1976, pages 364-370; A. KRASZEWSKI et al.: "An improved microwave method of moisture content measurement and control" * Figure 5; abstract; page 364, column 2, paragraph 1; page 367, columns 1-2 * ---	5,6,8-11,13-18	
A	US-A-3 818 333 (WALKER) * Figure 3; abstract; column 3, line 46 - column 4, line 22; column 5, lines 5-9 * ---	2,4	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	IEEE TRANSACTIONS ON INSTRUMENTS AND MEASUREMENT, vol. IM-35, no. 4, part 2, December 1986, pages 630-637; AGGARWAL and JOHNSTON: "Oil and water content measurement of sandstone cores using microwave measurement techniques" * Figures 5,4; abstract * -----	5,6,8	G 01 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	02-02-1990	ZINNGREBE U.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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